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2. Patent application number *(The Patent Office will fill this part in)* — ~~20 MAR 2004~~ 0406310.3

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   Hewlett-Packard Development Company, L.P.
   20555 S.H. 249
   Houston, TX 77070
   USA

   Patents ADP number *(if you know it)* — 880445200 I

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

   Method Of Applying Light Filters
   And Busbars To A Display Substrate

5. Name of your agent *(if you have one)*

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   Richard A. Lawrence
   Hewlett-Packard Ltd, IP Section
   Filton Road, Stoke Gifford
   Bristol BS34 8QZ

   1933005

   Patents ADP number *(if you know it)*

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? — Yes

   Answer YES if:
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Continuation sheets of this form	
Description	14
Claim(s)	5
Abstract	1
Drawing(s)	24 + 2

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	1
Request for a preliminary examination and search (Patents Form 9/77)	1
Request for a substantive examination (Patents Form 10/77)	
Any other documents (please specify)	Fee Sheet

11. I/We request the grant of a patent on the basis of this application.

Signature(s) Richard A. Lawrence Date 18/3/2004

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

Tony Judd Tel: 0117-312-8026

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DUPLICATE

METHOD OF APPLYING LIGHT FILTERS AND BUSBARS TO A DISPLAY SUBSTRATE

The present invention relates to a method of applying to a display substrate light filters and addressing busbars in a defined alignment relative to each other. The light filters may comprise a colour filter matrix of the substrate.

BACKGROUND TO THE INVENTION

The colour filter matrix is one of the most expensive components in a lightvalve-type backlit display, for example a liquid crystal polarisation switch mode display. The colour filter must be physically close to the electro-optic switching layer to avoid colour parallax, and must be aligned with at least the 'column' electrode patterning in the case of RGB colour stripes. Difficulties in achieving this alignment add to manufacturing costs.

A known production process involves patterning the colour matrix onto the final display substrate, planarising the matrix, and then forming the display cell. While this minimises the distance between the electro-optic switch and the colour filter element, it is very expensive and requires multiple lithographic steps.

A method of forming electrode patterns for a passively-addressed alphanumeric liquid crystal display (LCD) is described in US 3,902,790. The method involves providing gold-plated stripes for busbars and other conductive elements which are in areas where characters are not displayed, to provide highly conductive paths between display characters.

Methods of forming colour filters for LCDs by ink jet printing in pre-defined channels are described in JP 2003035814, JP 11142641, US 5,552,192 and US 5,576,070. Busbars are also used to address other types of displays, for example active matrix LCDs, in which operation of each pixel is controlled by a corresponding thin film transistor (TFT).

SUMMARY OF THE INVENTION

According to an aspect of the present invention there is provided a method of applying to a display substrate light filters and addressing busbars in a defined alignment relative to each other, the method comprising:

forming said light filters and said busbars on a surface of a transfer carrier;

adhering said light filters and said busbars to said display substrate; and

removing said transfer carrier.

By forming light filters that absorb visible light to produce colour, the method may provide a colour filter matrix which is aligned with the addressing busbars. The method is suitable for accurately aligning the colour filter matrix to the pixel matrix on a large area display. The display substrate may be glass or a plastics material. Additionally, or alternatively, the light filters may absorb UV light, which will enable them to be used in the formation of transparent electrode tracks in self-alignment with the busbars, as will be described in more detail later.

The method is of particular application to the manufacture of substrates for passive-addressed x/y matrix structures which

are elongate parallel lines or strips, and the invention will be illustrated with reference to this application. However the busbars could also take other shapes and forms of addressing metal structures. For example, the busbars may be used as addressing structures for active matrix LCDs and may form the TFT devices and crossovers for the addressing matrix.

The carrier substrate is preferably planar, and this planarity defines the final surface quality of the colour filter matrix/busbar combination. By using a carrier with a highly planar surface, the invention may provide a final, highly planar surface to the colour filter matrix or matrix/busbar combination without the need for a separate planarising operation. An advantage of using a carrier with a planar surface is that the surface quality of the display substrate onto which this is transferred does not have to be very good. If a polariser is laminated on the inner surface of the substrate then birefringence of the substrate becomes unimportant and a substrate with uncontrolled birefringence can be used.

The busbars and colour filters are transferred by adhesive onto the final display substrate. The alignment of the busbars and colour filters relative to each other on the transfer carrier is preserved on the display substrate. Before the transfer step there is the opportunity to deposit one or more optical films, for example polarisers or compensation retarders, which are also transferred and end up on the inside of the display. A polariser may be of conventional construction, adhered between the substrate surface and the colour filter matrix, or it may be a coatable

polariser which may be coated on the colour filter matrix or the substrate surface. The term "optical film" is used herein to denote a film which modifies at least one property of light incident thereon.

According to another aspect of the invention there is provided a method of applying to a display substrate light-filters and addressing busbars in a defined alignment relative to each other, the method comprising the steps of:

(a) forming a series of translucent dielectric structures on a planar surface of a carrier, each structure comprising a filter-receiving surface region and a raised levee, adjacent dielectric structures being spaced apart to define a trench therebetween;

(b) forming said busbars by at least partially filling each of said trenches with an electrically conductive material;

(c) depositing a light-filter material on each of said filter-receiving surface regions to form a series of light-filters;

(d) affixing said light-filters and levees to a translucent display substrate by means of a translucent adhesive material; and

(e) removing said carrier.

The dielectric structures may be formed on the carrier by any suitable means, for example embossing, micromoulding, laser ablation or photolithography. In a preferred embodiment the dielectric material is optically transparent and is formed by UV micromoulding, as taught in WO 96/34971, the content of which is incorporated herein by reference.

An embodiment of the invention uses the same dielectric structures to define both the position of the busbars and the formation of defined channels into which the colour filter material can be deposited. It is preferred that the filter-receiving surface is generally flat but suitably roughened to help the applied colour filter material wet out and key in. A preferred method of depositing the colour filter material is by inkjet deposition, for example drop-on-demand inkjet printing.

Once the busbars and colour filters are transferred to the final substrate a transparent conducting material (eg, PEDOT or ITO) is applied and, if required, patterned, using a serial (eg, laser ablation) aligned technique, or by using the colour filter/busbar construction as a shadowing/alignment system.

A combination of filters and busbars may also be used to prove transparent electrode structures in alignment with the busbars even where there is no colour filter matrix. By using other filter materials instead of colour filters, for example UV-absorbing filters, with UV-transmitting dielectric structures, the electrode structures may be patterned in the same manner as when colour filters are present.

The trenches and levees will typically be linear structures that will extend across the length of the substrate. Any desired spacing may be used, for example they may be 50 to 200 μm apart, notably about 100 μm apart, and they may be many metres in length. Although the colour-receiving regions are preferably roughened to promote wetting of the surface by the colour filter material, the tops of the levees are

preferably smooth or otherwise surface-treated to discourage wetting and flow of one colour material into an adjacent channel.

Other aspects and benefits of the invention will appear in the following specification, drawings and claims.

The invention will now be further described, by way of example only, with reference to the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1 to 9 illustrate stages in the manufacture of a display substrate having colour filters, busbars and electrode tracks in a predetermined alignment, in accordance with an embodiment of the present invention;

Figures 10 to 13 illustrate stages in a method of manufacture in accordance with an alternative embodiment of the present invention;

Figures 14 to 17 illustrate stages in a method of manufacturing a device substrate in accordance with a further alternative embodiment of the present invention;

Figures 18 to 21 illustrate stages in a method of manufacturing a device substrate in accordance with still further alternative embodiment of the invention;

Figures 22 and 23 are schematic sectional and plan views respectively of a display device incorporating a display substrate manufactured in accordance with an embodiment of the invention; and

Figure 24 is a perspective view corresponding to Figure 3, illustrating another alternative embodiment of the present invention.

DETAILED DESCRIPTION

In the drawings, different parts have been enlarged or reduced to aid illustration of the invention. The drawings are therefore not to scale.

A carrier 1 for use in the invention is shown in Figure 1. The carrier 1 comprises a base film 2 on which is coated a planar, conductive layer 3. The carrier 1 may be rigid or flexible. In this example, the base film 2 comprises 150 μm thick PET and the conductive layer 3 is copper metal of about 1 μm thickness. In this example, the conductive copper layer 3 is optically flat and has been passivated by immersion in 0.1 N potassium dichromate solution for 5 minutes, rinsed with deionised water and air dried.

A multiple-level, controlled-roughness pattern of dielectric structures 4 is formed on the surface of the conductive layer 3 of the carrier 1 (Figure 2). The dielectric material is optically transparent and in this example is formed by micromoulding as taught in WO 96/35971. The dielectric structures 4 are separated from each other by a series of parallel trenches 5, in which the busbars will be formed. Each structure 5 comprises a rough, planar area 6 and a raised levee 7. The planar areas (filter-receiving surfaces) 6 will accept the colour filter layers and the levees 7 will separate the colour filters. The trenches and levees are substantially linear structures which will run across the length or width of the substrate to which they are transferred. They are typically about 100 μm apart and up to many metres in length. The rough planar surfaces 6 will permit spreading of an applied ink jet coating and may

optionally be treated to promote wetting. The levees 7 are smooth and may optionally be treated to further discourage wetting and flow of one colour material into an adjacent planar area.

Referring now to Figure 3, conductive material 8 is formed in the trenches 5. The conductive material is preferably a metal and, in this example, is formed by additive electroforming. It is preferred that the conductor 3 forms the cathode of an electrolytic cell with a nickel anode and standard nickel sulphamate-based electrolyte. Plating may be carried out by DC, with pulsed or biased AC current being used to fill in the trenches completely. Other known electroplating or electroless plating techniques may be employed. Suitable metals include nickel, copper and gold.

The resulting metallised structure is coated with colour filter material (Figures 4 and 5). In this example the material is deposited by ink jet printing in the colour-receiving planar areas 6 to produce red 9, green 10, and blue 11 colour filter triads. Other colour combinations may optionally be used. Alternatively, for an embodiment which will be described later, the filters 9, 10, 11 may be UV absorbing but substantially transmit all wavelengths of visible light. In a preferred embodiment, the colour filter material is a dyed UV-curable resin (Brewer Science, Inc PDC). Examples of suitable inkjet nozzles include thermal and piezo nozzles, although other depositing means and techniques may be used. The alignment of droplets is not critical because the filter material is allowed to spread out across the planar regions 6 and is constrained by the levees 7 from flowing into the adjacent channels. The filter

material 9, 10, 11 may be cured after coating, for example by UV exposure and/or thermal treatment.

After curing of the colour filters 9, 10, 11, the resulting structure is then treated with a transfer adhesive 12, and the final display substrate 13 is laminated and the adhesive 12 is cured (Figure 6). In a preferred embodiment the transfer adhesive 12 is a UV-curable material such as NOA81 (Norland Optical Products) but may be thermal- or moisture-cured. The display substrate 13 is preferably a plastics material, for example PEN (DuPont Teijin Teonex Q65), PES (Sumitomo Bakelite) or polyArylate (Ferrania SpA - Arylite), but could comprise glass, preferably a UV-translucent glass.

The carrier 1 is then peeled away, leaving the colour filter/busbar laminate shown in Figure 7.

To form electrodes, a transparent conductor 14 is deposited onto the released surface of the laminate structure, as illustrated in Figure 8. The conductor 14 may comprise indium oxide, tin oxide, indium tin oxide (ITO) or the like, but is preferably an organic conductor such as PEDOT:PSS (Bayer Baytron P).

The transparent conductor 14 is then selectively etched or patterned to provide transparent electrodes 17. In the present embodiment, illustrated in Figure 9, the conductor 14 is photopatterned by illuminating the laminate from the reverse (substrate 13) side. The colour filters 8, 10, 11 are at least partially opaque to UV, whilst the substrate 13, transfer adhesive 12 and dielectric 4 are not. Consequently, substantially the only UV transparent areas are the raised

levees 7. In the preferred embodiment, PEDOT:PSS is bleached directly by the incident UV light to form the electrode structures 17. Alternatively, standard photoresists and etching may be employed, as will be described later. The resulting display substrate has colour filters, busbars and transparent electrodes in a predetermined alignment. It may be incorporated in a display, for example a liquid crystal display, using fabrication techniques well known *per se* to those skilled in the art of display manufacture.

Referring now to Figures 10 to 13, a modification of the process in illustrated in which a coatable polariser layer 15a is applied on top of the colour filter laminate structure shown in Figure 5. After curing of the coatable polariser layer 15a, the resulting structure is adhered to a display substrate 13 using a transfer adhesive 12, followed by removal of the carrier 1, application of a transparent conductor 14, and formation of transparent electrodes 17 in a manner as previously described. A suitable coatable polariser material is sold by Optiva, Inc. Coatable polarisers are described in Bobrov, Y., Cobb, C., Lazarev, P., Bos, P., Bryand, D., Wonderly, H. "Lyotropic Thin Film Polarisers", *Society for Information Display, Int.Symp.Digest of Technical Papers*, Long Beach, California May 16-18, 2000, Vol. XXXI, 1102-1107.

The process illustrated with respect to Figures 14 to 17 is similar to that illustrated with respect to Figures 6 to 9, with the difference that the colour filter/busbar structure shown in Figure 5 is adhered to a conventional polariser 15 which is in turn adhered to the display substrate 13. Methods for adhering conventional polarisers to display

substrates will be well known to those skilled in the art of LCD manufacture. Other optical films, such as compensation retarders, may also optionally be laminated inside the display without affecting the planarity and performance of the electro-optic layer interface.

An alternative method of forming electrode tracks 17 from the transparent conductor layer 14 shown in Figure 16 is illustrated in Figures 18 to 22. A positive photoresist material 16 (Shipley 1805) is coated on the transparent conductor 14 (Figure 18). UV illumination through the substrate 13 transmits UV light through the levees 7 (Figure 19) thereby curing the resist 16 in regions corresponding to the levees 7. The resist 16 is developed (Shipley Microposit Developer) to remove the exposed material (Figure 20), and the transparent conductor 14 is then wet or dry etched (for example by sodium hypochlorite solution) to produce electrode tracks 17 (Figure 21). Finally, the resist 16 is removed to leave the final substrate with electrode tracks as shown in Figure 17. The resist 16 may be removed by means of standard solvents or a commercial resist stripper, for example acetone.

For a display substrate in which colour filters are not required, busbars may be aligned with transparent electrode structures formed thereon using the techniques described above, but using UV-absorbing filters 9, 10 and 11 that absorb little or no visible light.

Turning now to Figures 22 and 23, an example of an electro-optic display device using a substrate manufactured in accordance with an aspect of the present invention is

described. The device is a liquid crystal display (LCD) in this example, but the substrates may be employed in other types of display device. The device comprises a first display substrate 13 and a second display substrate 18, each of which is provided with an adhered polariser 15 in a manner known *per se*. The structure shown in Figure 17 is provided with an alignment layer 19 for inducing a desired local uniform alignment in molecules of a liquid crystal material 27. The polariser 15 on the second substrate 18 is affixed to a UV-blocking layer 21 by a layer of adhesive 15. The UV-blocking layer 21 has been used to form electrode tracks 17 on busbars in the layer shown schematically as 20. The layer 20 contains busbars, dielectric structures, and UV-filters (not shown). The lower electrode structures 17 are also provided with an alignment layer 19. Any desired alignment layers 19 known to those skilled in the art may be used, for example rubbed polyimide. Depending on the type of display mode, the two alignment layers may induce the same type of alignment (for example planar, tilted planar, or homeotropic) or different types. Where both alignment layers 19 produce a planar or tilted planar alignment, the direction of alignment may be the same or different. For example, in a twisted nematic display, both alignment layers may induce planar alignment, with the orientation of the alignments being perpendicular.

The display is provided with a peripheral seal 25 to retain the liquid crystal material 27. In the example illustrated in Figure 23, a plurality of busbars 22 form row-addressing electrodes and a plurality of busbars 23 form column-addressing electrodes. Pixels 26 are defined at locations where row and column electrodes overlap, and characters or

other indicia may be displayed in regions where a sufficient voltage is applied across appropriate pixels, thereby modifying the optical behaviour of the liquid crystal in the region of the pixels so that there is a visible difference when the display is viewed between the polarisers 15.

Other features known *per se* may optionally be included in the display by conventional means. Examples include backlights and one or more antiglare layers.

Each busbar 8 need not be in the middle of its associated electrode track 17, but may be located at any desired contact line on the track. In Figure 24, part of a transfer carrier is shown, in which the busbars 8 are formed adjacent to the levees 7 on the planar conductive surface 3. Subsequent UV exposure of a transparent conductor through the levees 7 will result in the busbars being aligned at the sides of corresponding transparent electrode tracks.

It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment, may also be provided separately, or in any suitable combination.

It is to be recognized that various alterations, modifications, and/or additions may be introduced into the constructions and arrangements of parts described above without departing from the scope of the present invention as specified in the claims.

CLAIMS

1. A method of applying to a display substrate light filters and addressing busbars in a defined alignment relative to each other, the method comprising:

forming said light filters and said busbars on a surface of a transfer carrier;

adhering said light filters and said busbars to said display substrate; and

removing said transfer carrier.

2. A method according to claim 1, wherein said surface of said transfer carrier is planar.

3. A method according to claim 1 or claim 2, wherein said light filters each absorb at least one wavelength band of visible light.

4. A method according to claim 3, wherein said light filters comprise at least one which transmits red light, at least one which transmits green light, and at least one which transmits blue light.

5. A method according to any preceding claim, wherein said light filters at least partially absorb ultraviolet light and are spaced apart from each other by regions that are substantially transmissive of UV light.

6. A method according to claim 5, further comprising the steps of:

forming a transparent conductor layer on said busbars after removal of said transfer carrier, said transparent

conductor layer being capable of being rendered substantially non-conductive after exposure to UV light of sufficient intensity and duration;

illuminating said conductor layer with UV light of sufficient intensity and duration through said display substrate as to cause substantial loss of conductivity in regions of said conductor layer corresponding to spaces between said light filters;

thereby forming a plurality of transparent electrode tracks, each of which is in electrical contact with a busbar.

7. A method according to claim 5, further comprising the steps of:

forming a transparent conductor layer on said busbars after removal of said transfer carrier;

applying a layer of positive photoresist material to said conductor layer;

illuminating said photoresist material with UV light of sufficient intensity and duration through said display substrate as to effect a chemical change in exposed regions of said photoresist material corresponding to spaces between said light filters;

developing said photoresist so as to remove said photoresist in said exposed regions;

etching said conductor layer in regions where said photoresist has been removed, thereby forming a plurality of transparent electrode tracks, each of which is in electrical contact with a busbar; and

removing remaining photoresist.

8. A method of applying to a display substrate light-filters and addressing busbars in a defined alignment

relative to each other, the method comprising the steps of:

(a) forming a series of translucent dielectric structures on a planar surface of a carrier, each structure comprising a filter-receiving surface region and a raised levee, adjacent dielectric structures being spaced apart to define a trench therebetween;

(b) forming said busbars by at least partially filling each of said trenches with an electrically conductive material;

(c) depositing a light-filter material on each of said filter-receiving surface regions to form a series of light-filters;

(d) affixing said light-filters and levees to a translucent display substrate by means of a translucent adhesive material; and

(e) removing said carrier.

9. A method according to claim 8, wherein said light-filters are colour filters.

10. A method according to claim 8 or claim 9, wherein said light-filters are at least partially UV-absorbent.

11. A method according to any of claims 8-10, wherein said light-filter material is deposited *via* an inkjet print head.

12. A method according to claim 10, further comprising the steps of applying a layer of a translucent conductor material in contact with said busbars, and treating said conductor material so as to form it into translucent electrode tracks in alignment with and in contact with said busbars, by means of UV light transmitted through said display substrate and

said levees.

13. A method according to claim 8, further comprising providing a polariser between said levees and said display substrate.

14. A method according to claim 13, wherein said polariser is provided by applying a coatable polariser layer on said light-filter layers and levees.

15. A method according to claim 13, wherein said polariser is provided adhered on said display substrate and wherein said step of affixing said light-filters and levees to said display substrate comprises affixing said light-filters and levees to said polariser.

16. A method according to claim 8, further comprising providing an optical film between said levees and said display substrate.

17. A method according to claim 16, wherein said optical film comprises a compensation retarder.

18. A method according to any of claims 8-17, wherein said surface of said carrier is conductive, and wherein said busbars are formed by electroplating.

19. A method of applying to a display substrate colour filters and addressing busbars in a defined alignment relative to each other, the method comprising the steps of:

(a) forming a series of translucent dielectric structures on a planar, conductive surface of a carrier,

each structure comprising a wettable surface region and a raised levee, adjacent dielectric structures being spaced apart to define a trench therebetween;

(b) forming said busbars by at least partially filling each of said trenches with a metal by electroplating;

(c) depositing a coloured material on each of said wettable surface regions by inkjet printing to form a series of colour filters;

(d) affixing said colour filters and levees to a translucent display substrate by means of a translucent adhesive material; and

(e) removing said carrier.

20. A transfer carrier comprising a surface on which is releasably mounted a plurality of light filters and a plurality of busbars in a defined alignment relative to each other.

21. A transfer carrier according to claim 20, wherein said surface is planar.

22. A display substrate obtained by the method of any of claims 1-19.

23. A method of applying light filters and busbars to a display substrate substantially as herein described with reference to the drawings.

ABSTRACT

METHOD OF APPLYING LIGHT FILTERS AND BUSBARS TO A DISPLAY SUBSTRATE

A method of applying to a display substrate (13) light filters (9, 10, 11) and addressing busbars (8) in a defined alignment relative to each other comprises:

forming said light filters (9, 10, 11) and said busbars (8) on a surface of a transfer carrier (1);

adhering said light filters (9, 10, 11) and said busbars (8) to said display substrate (13); and

removing said transfer carrier (1).

Figure 6

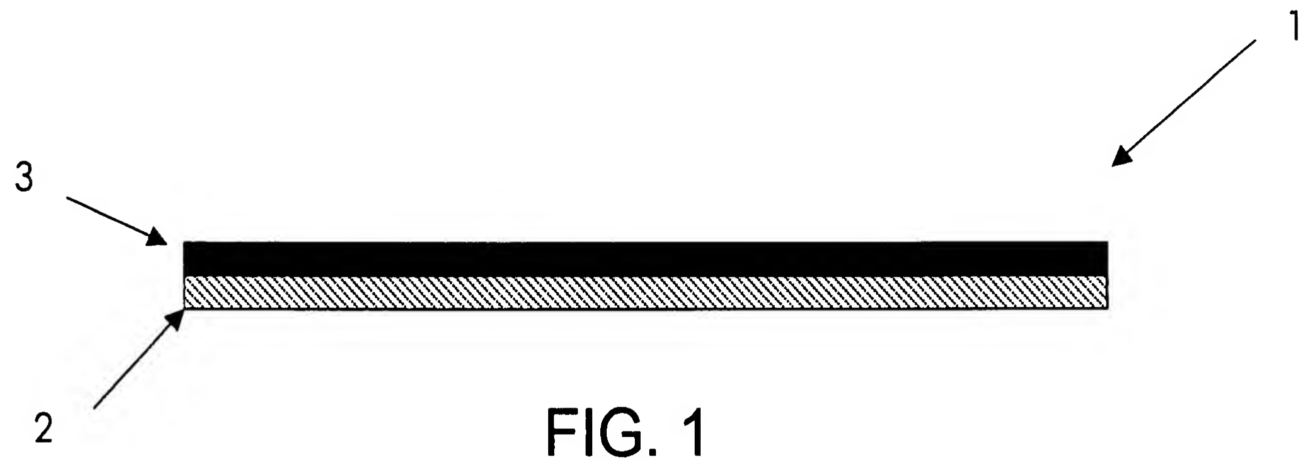

FIG. 1

2/24

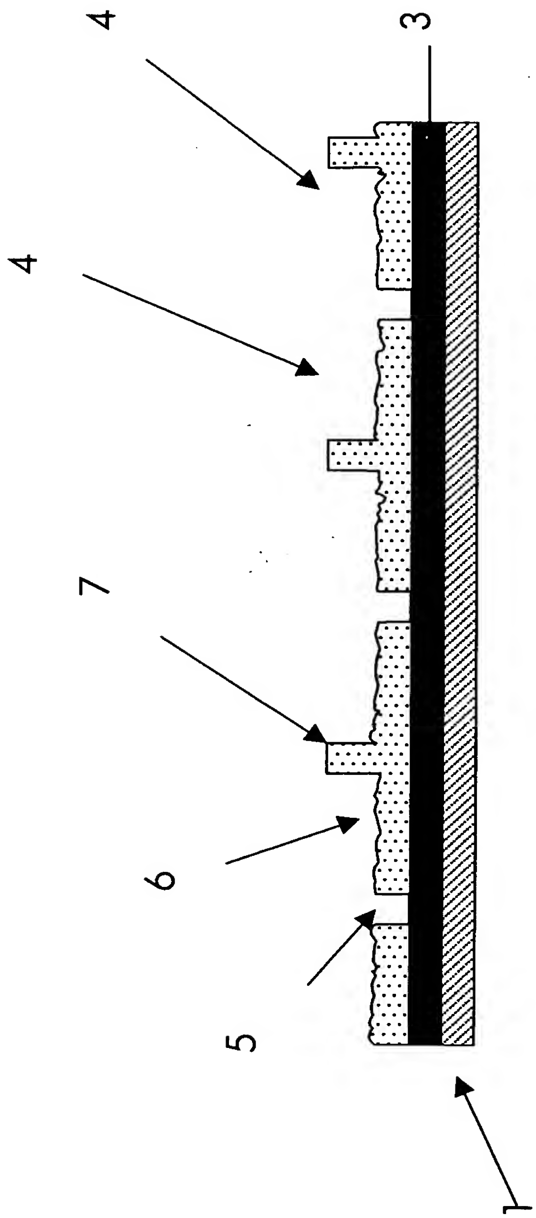

FIG. 2

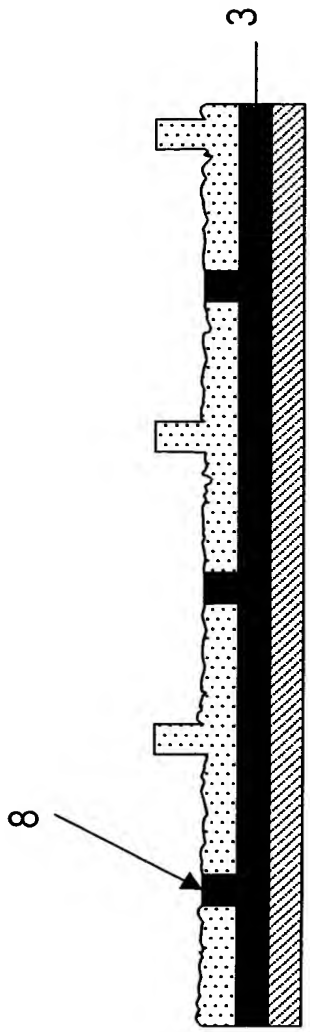

FIG. 3

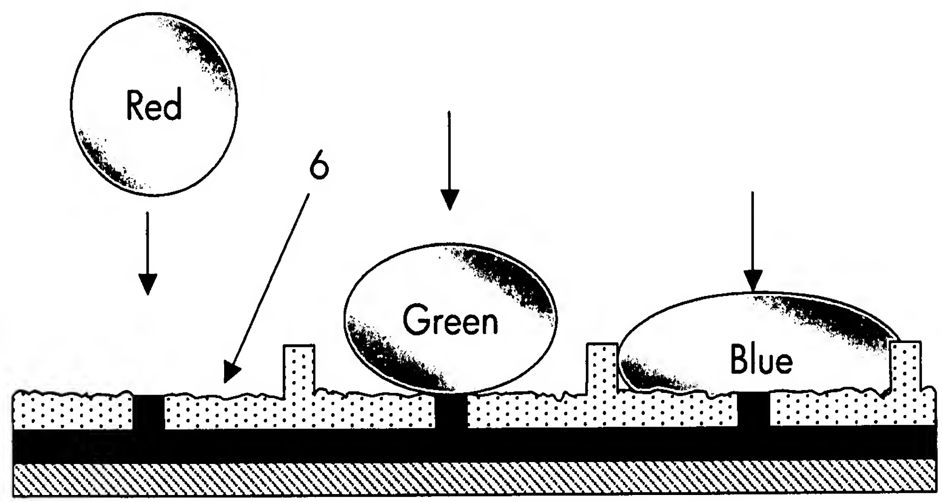

FIG. 4

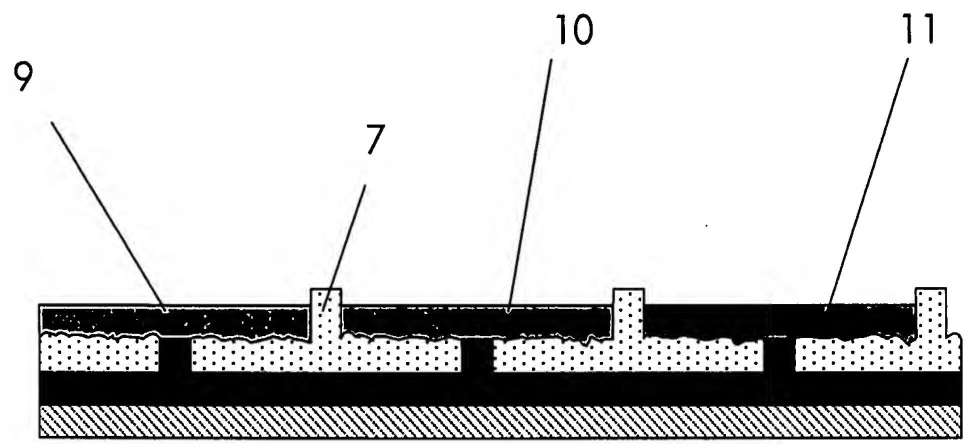

FIG. 5

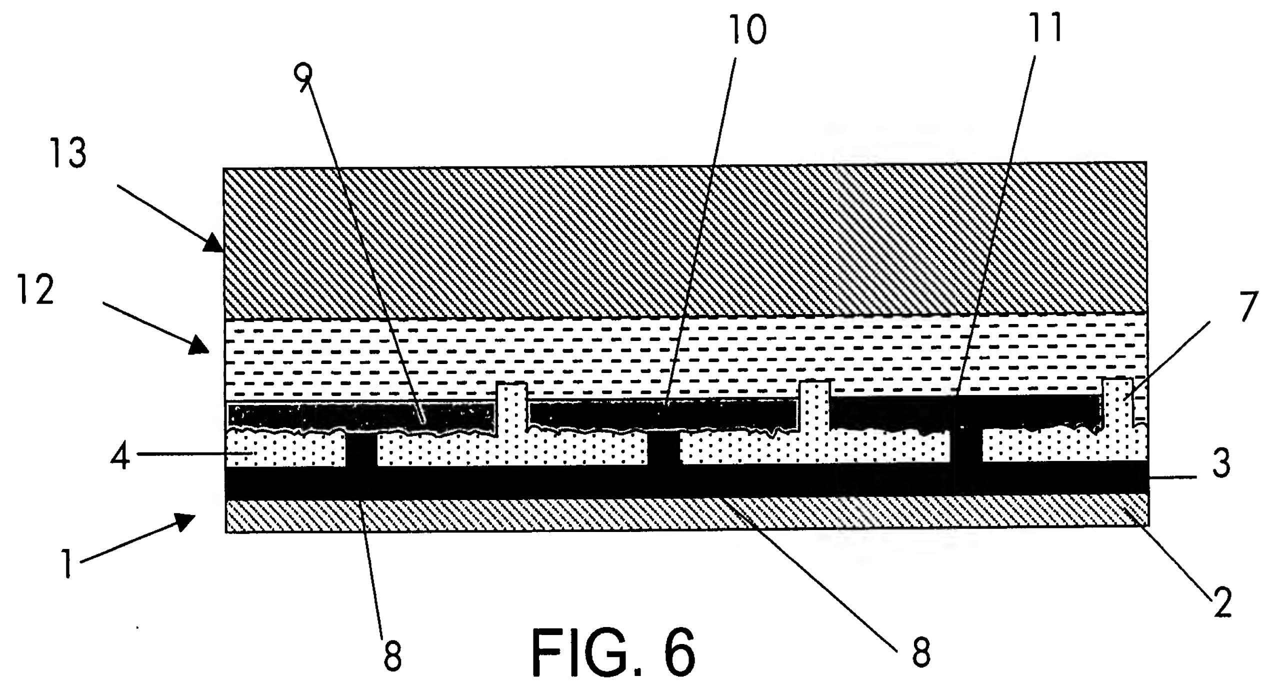

FIG. 6

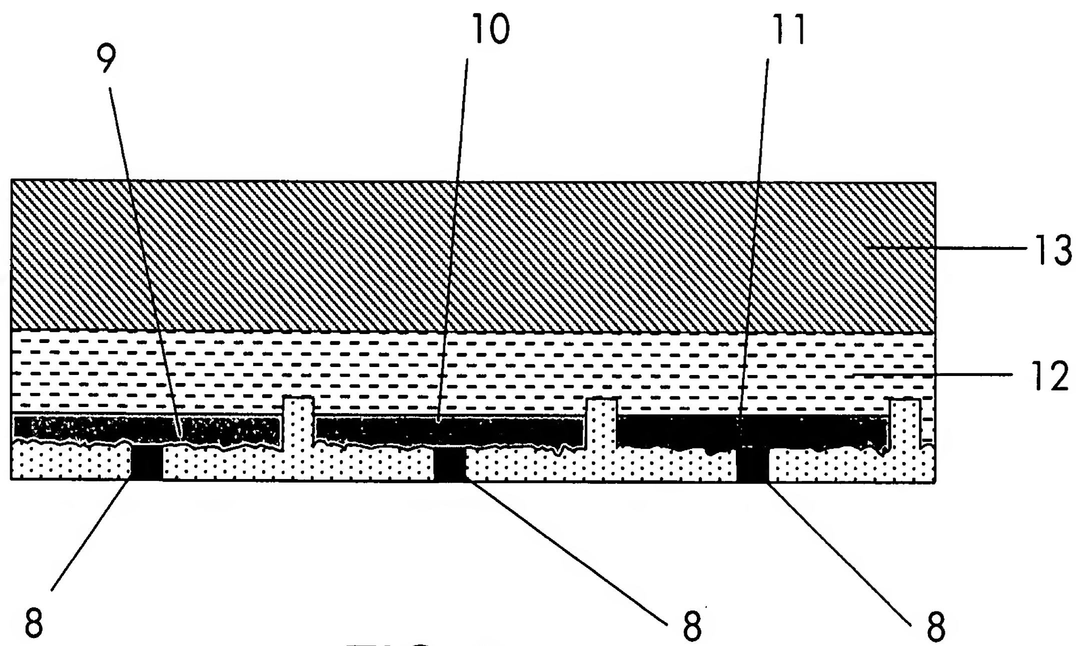

FIG. 7

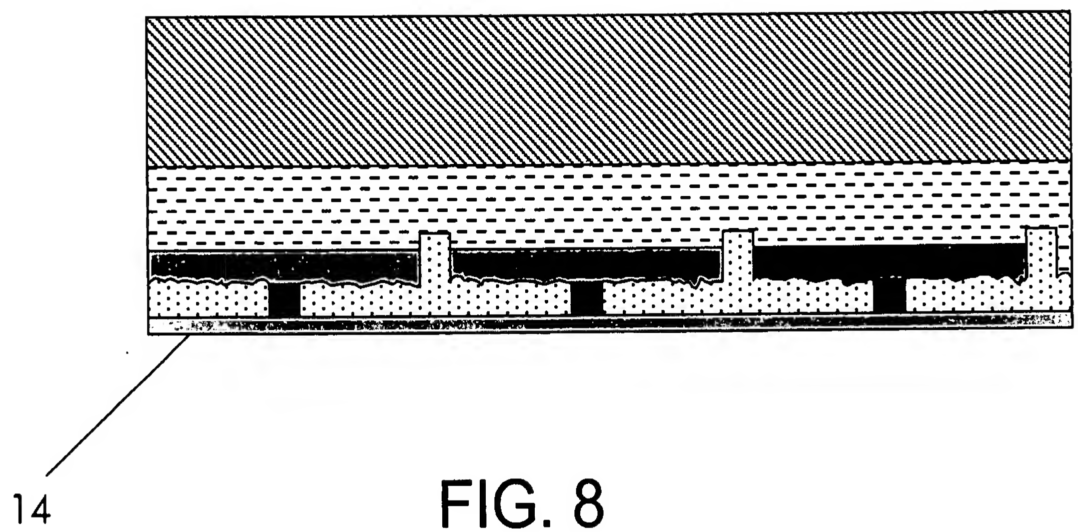

FIG. 8

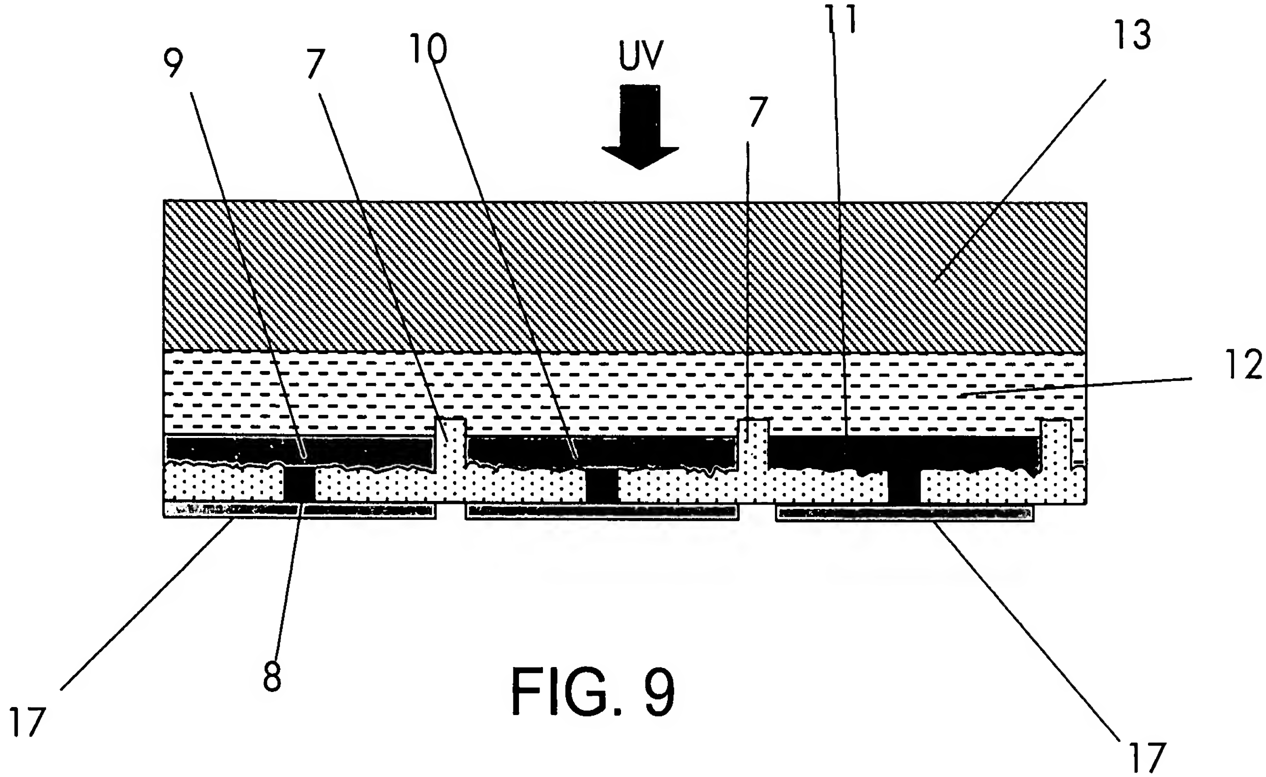

FIG. 9

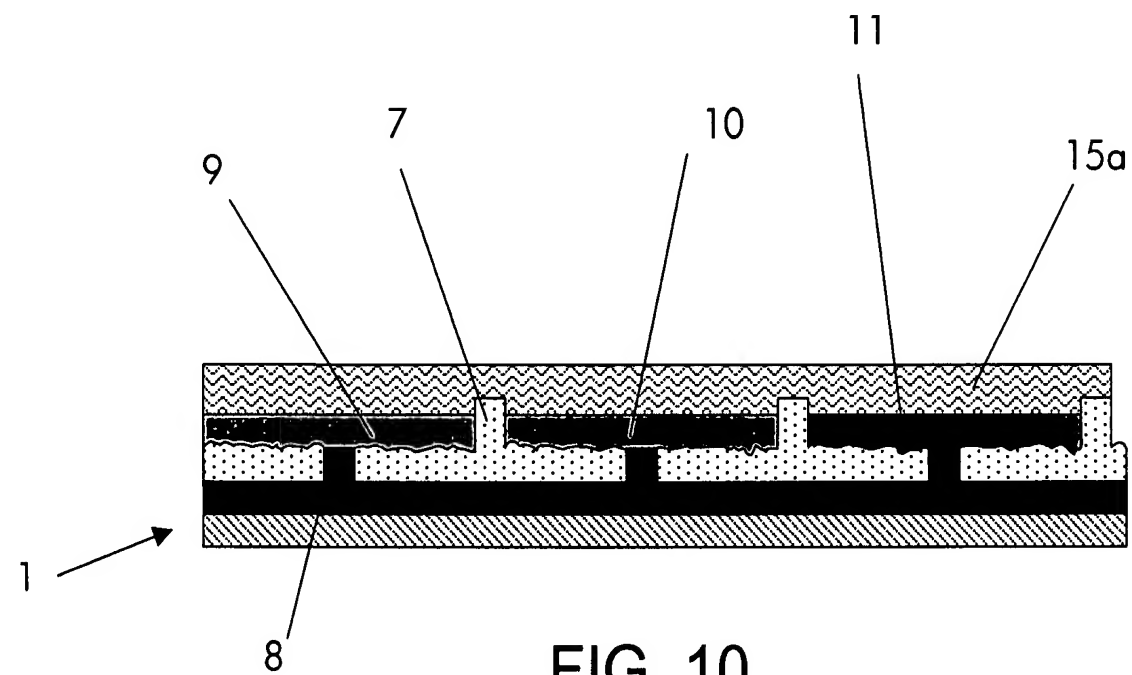

FIG. 10

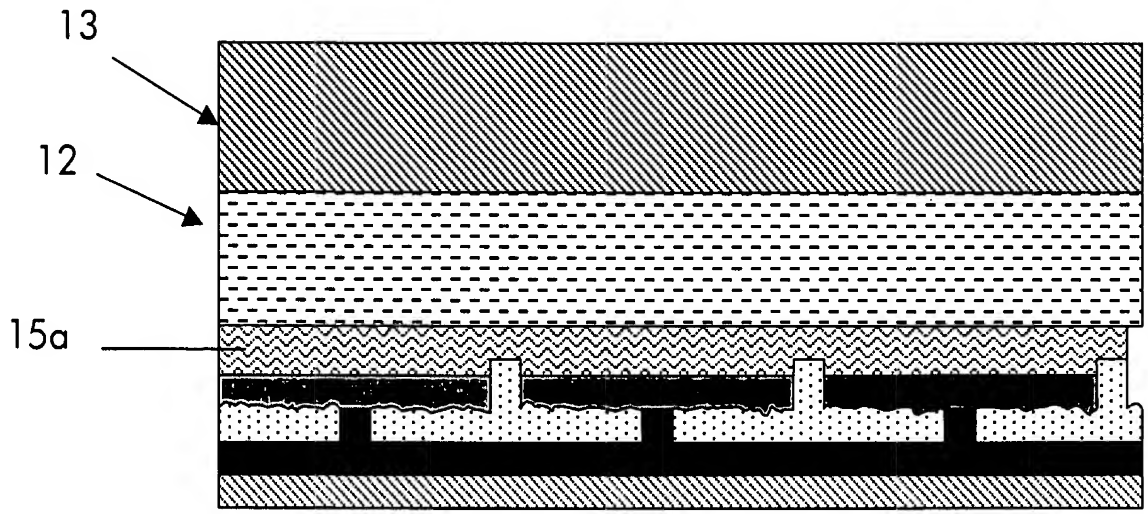

FIG. 11

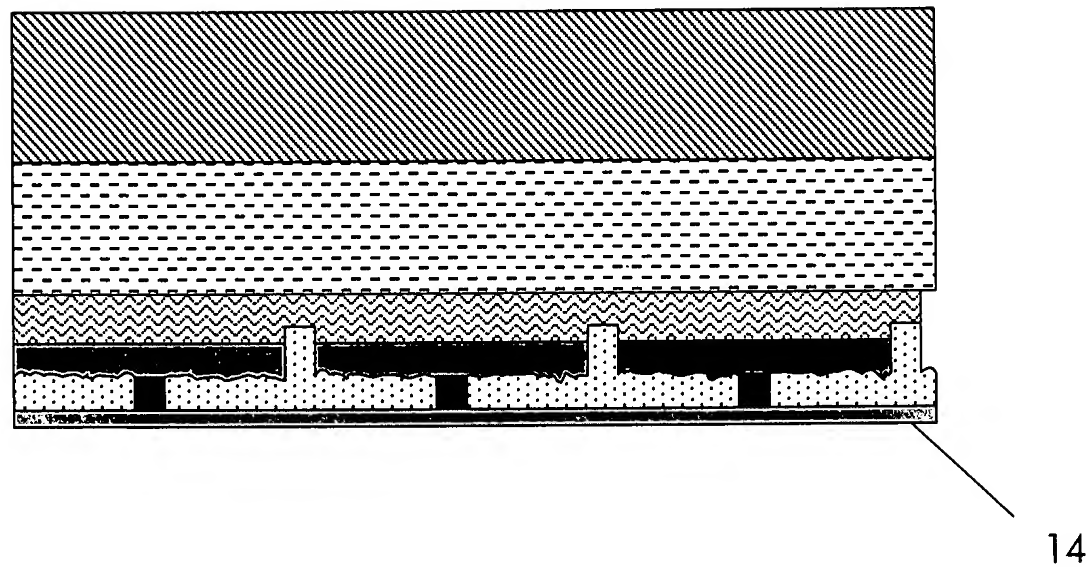

FIG. 12

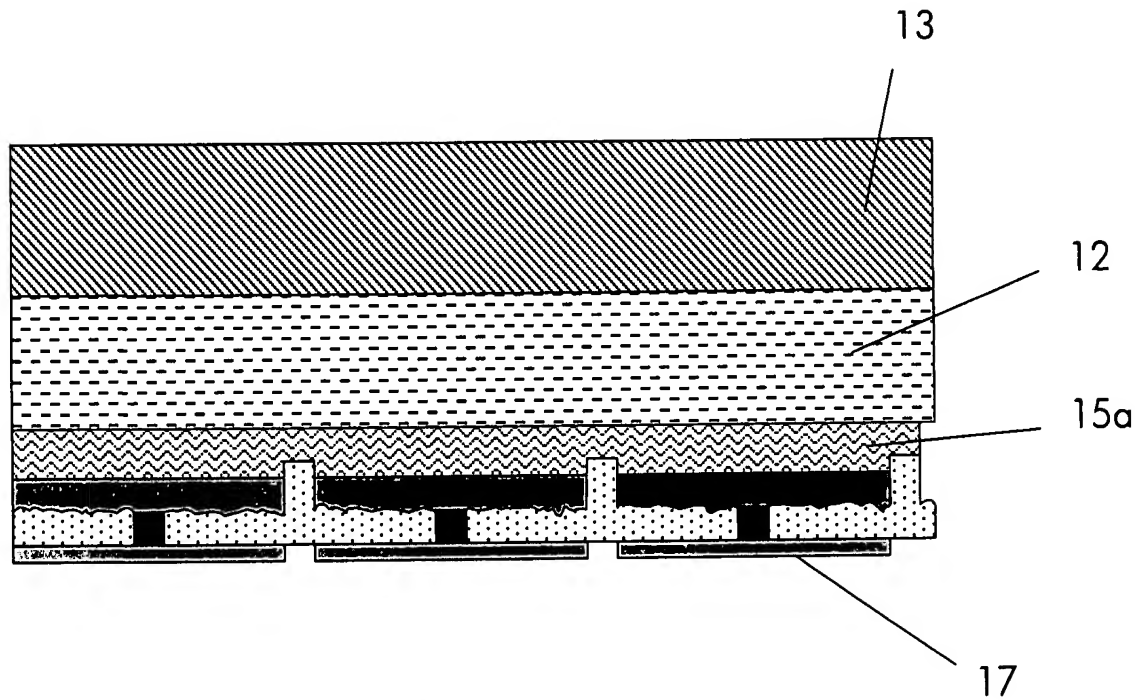

FIG. 13

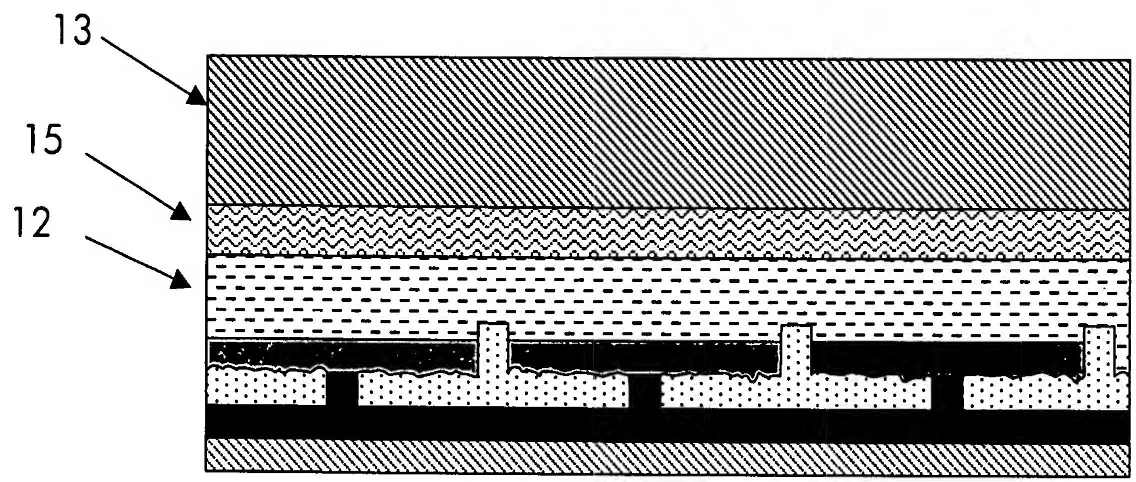

FIG. 14

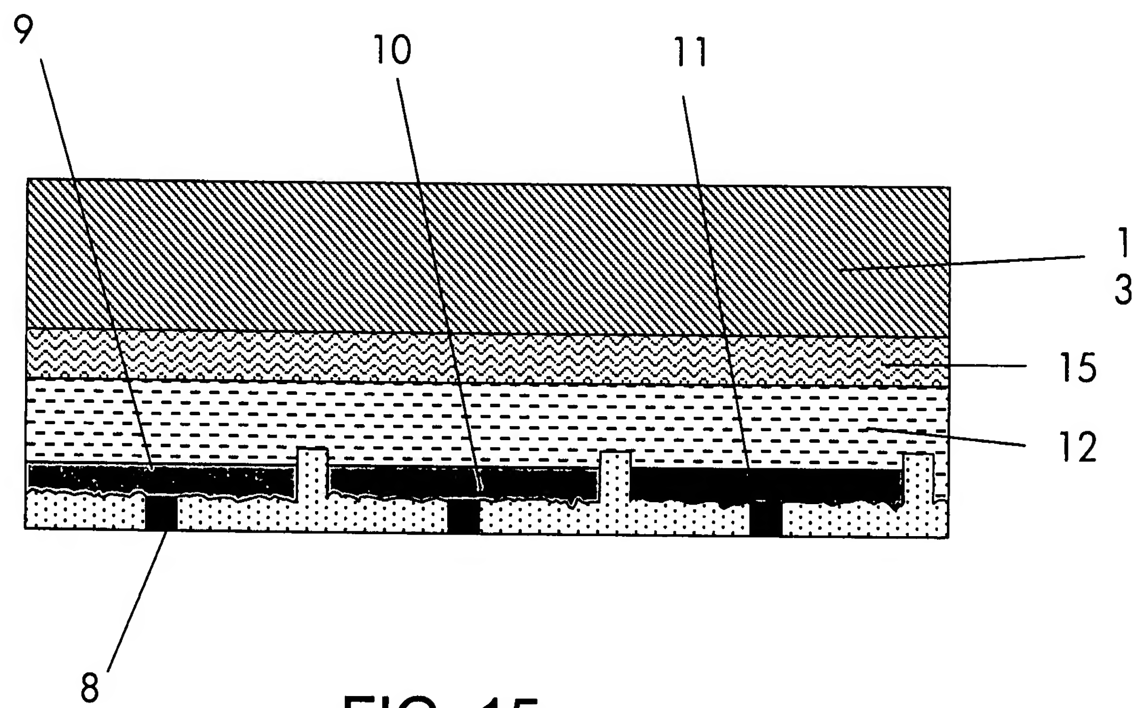

FIG. 15

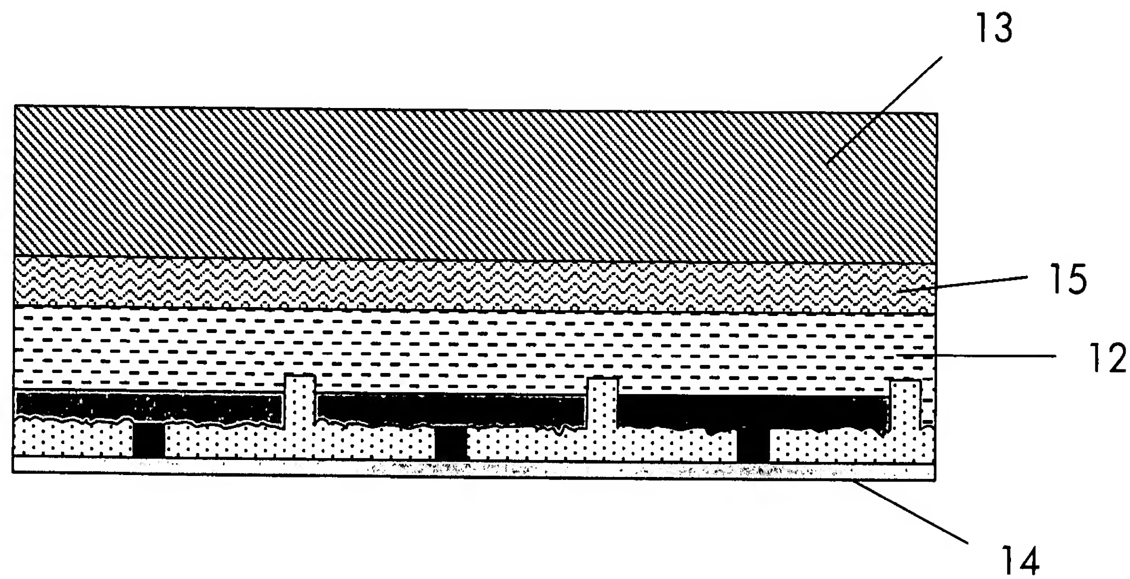

FIG. 16

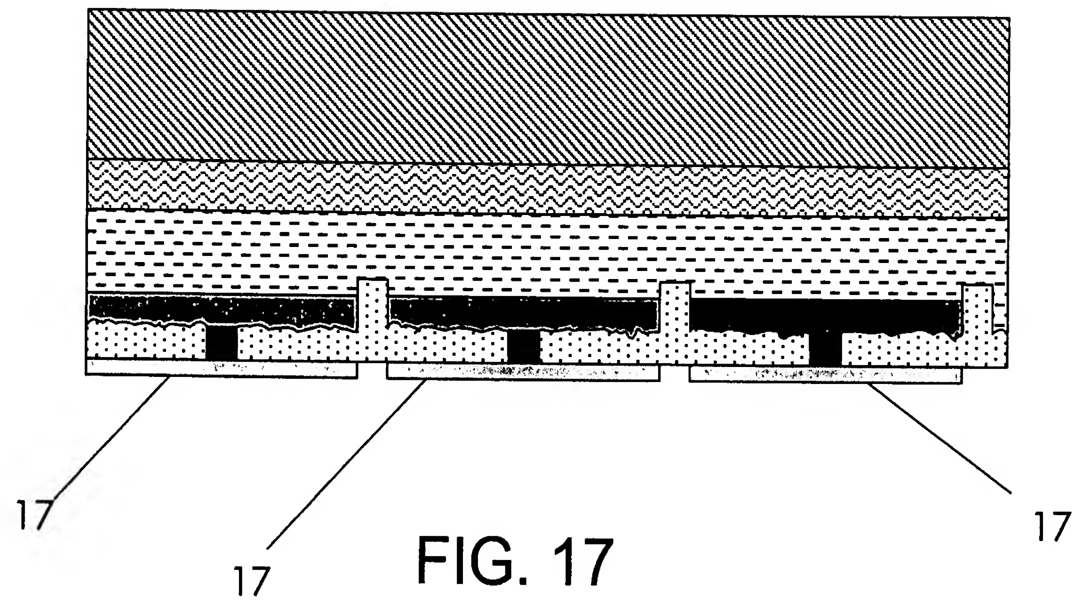

FIG. 17

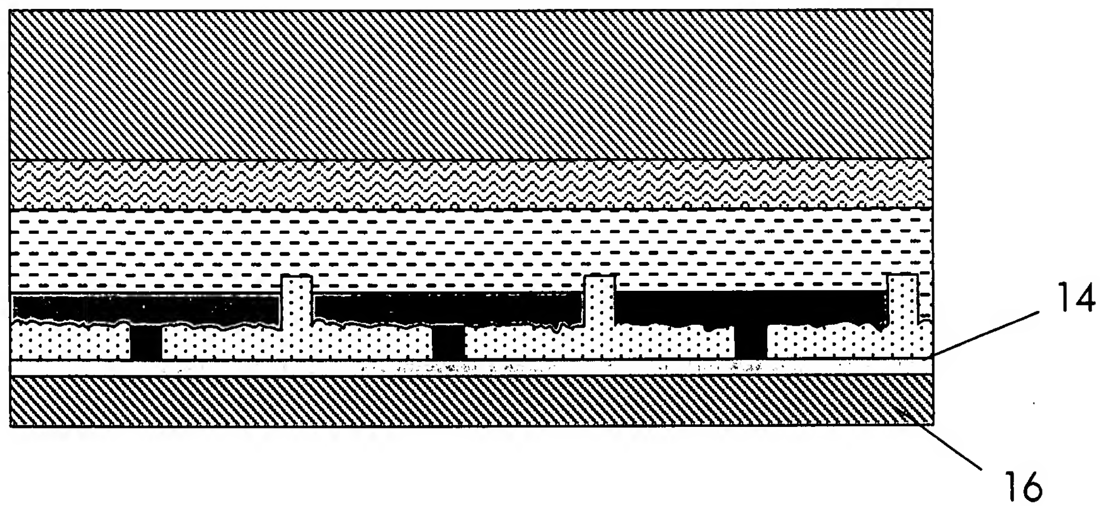

FIG. 18

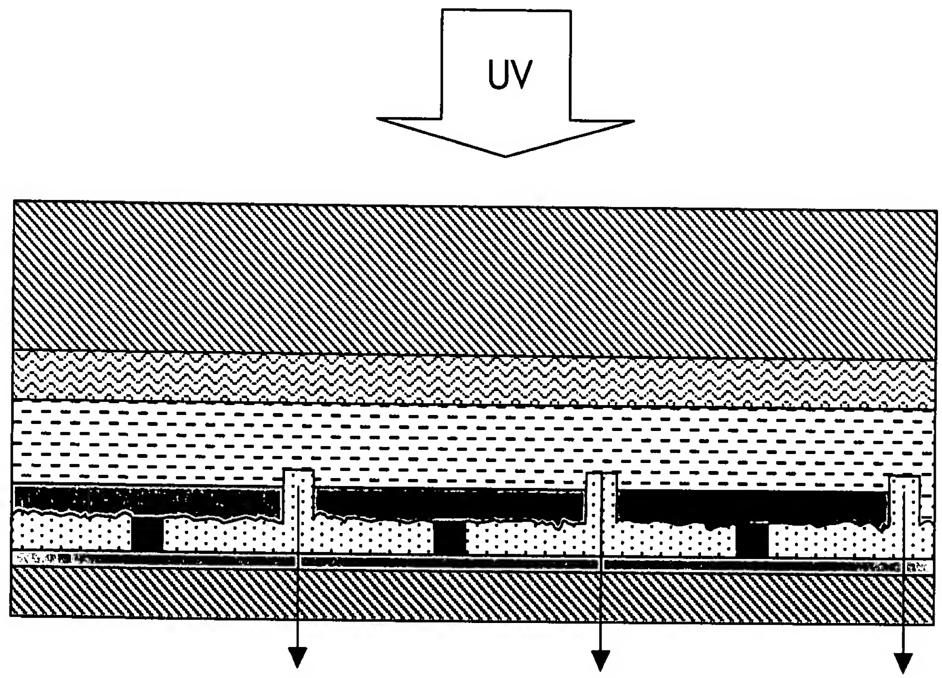

FIG. 19

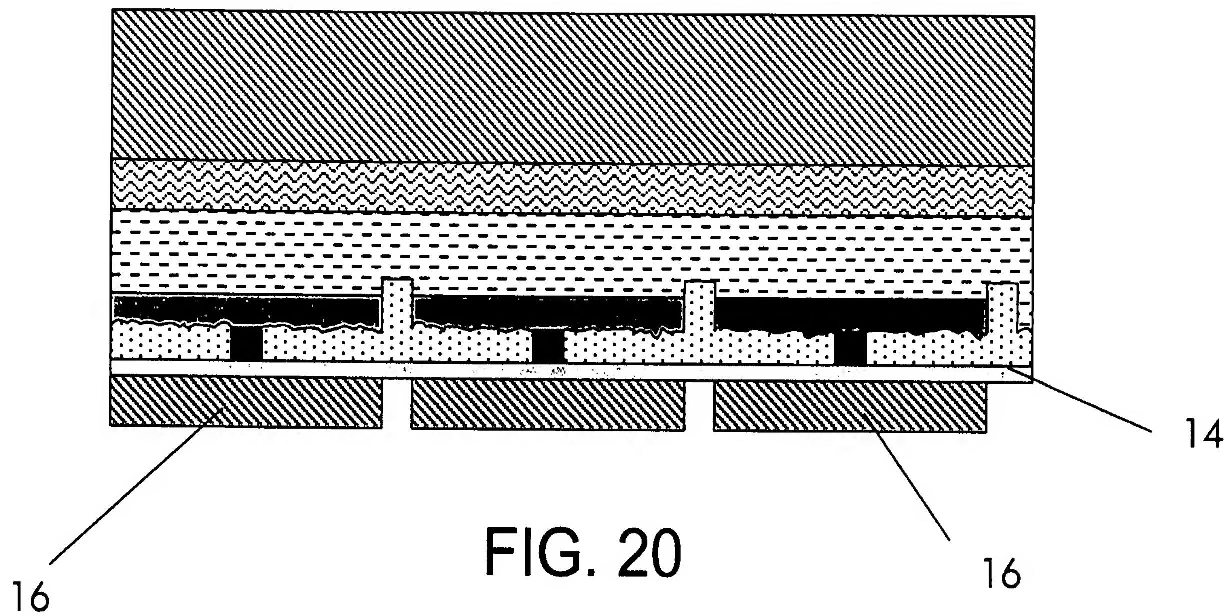

FIG. 20

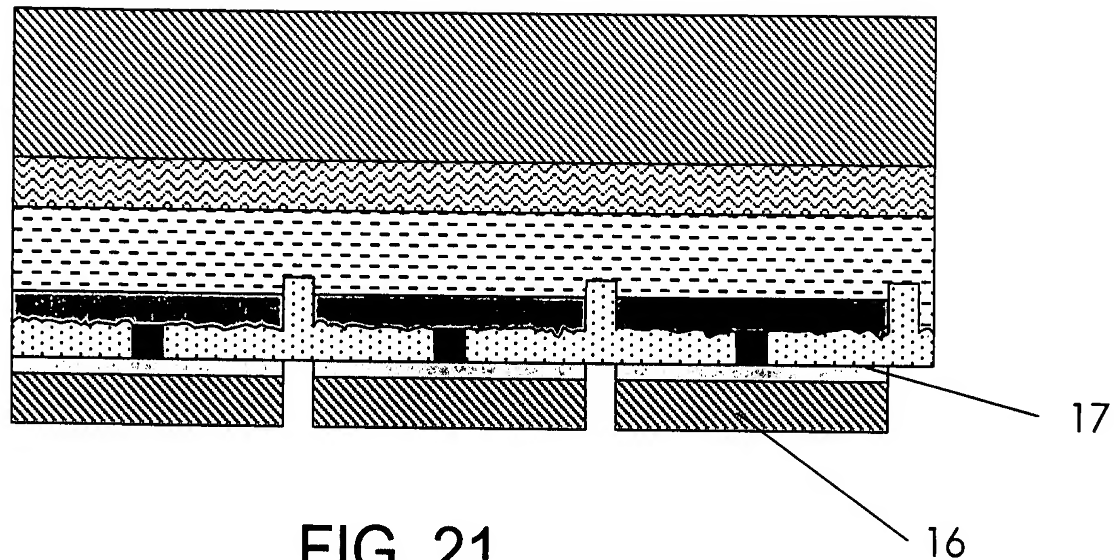

FIG. 21

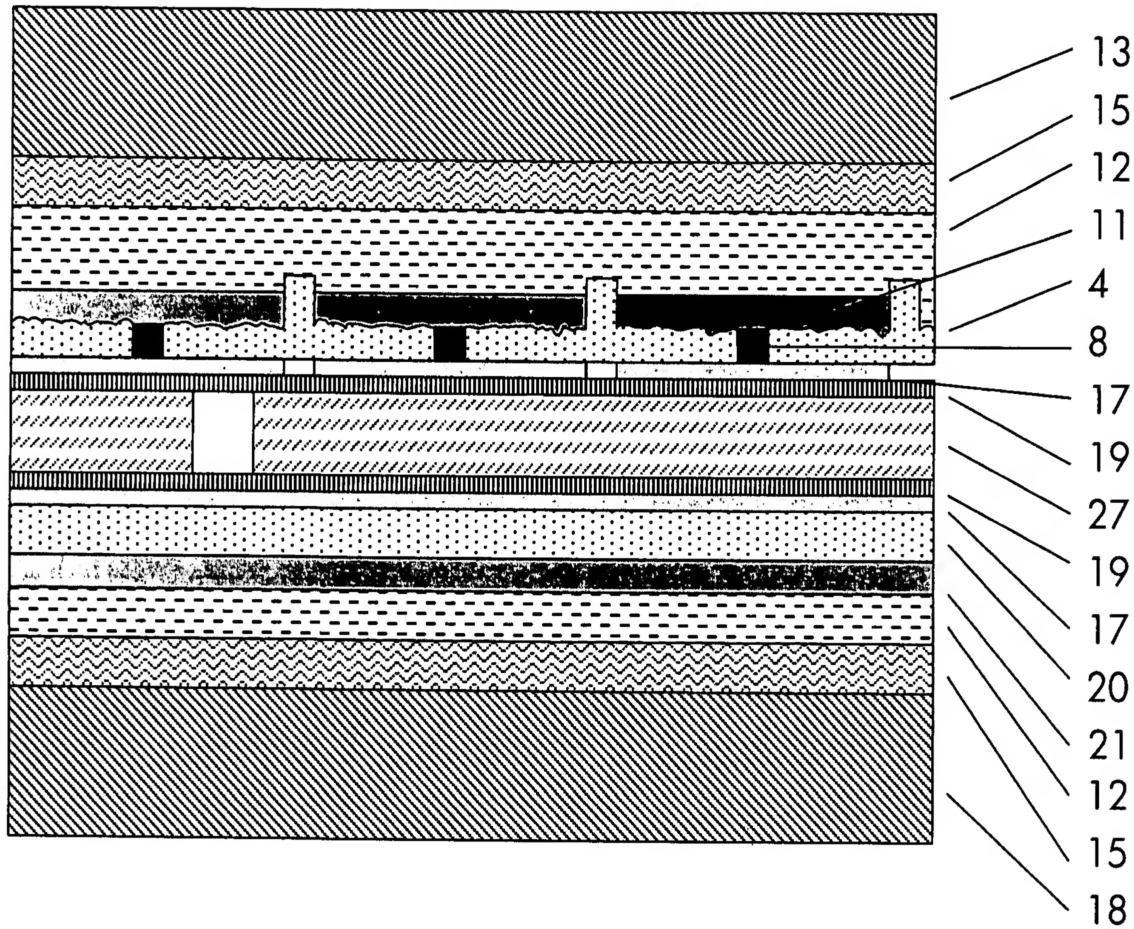

FIG. 22

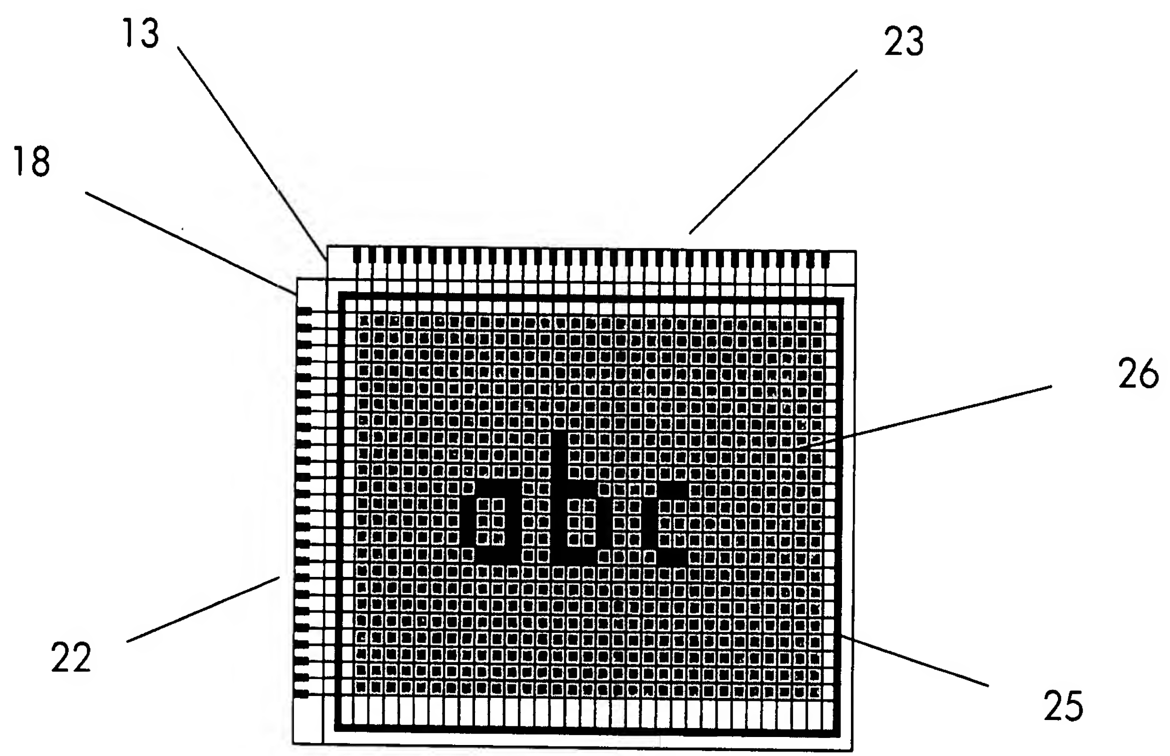

FIG. 23

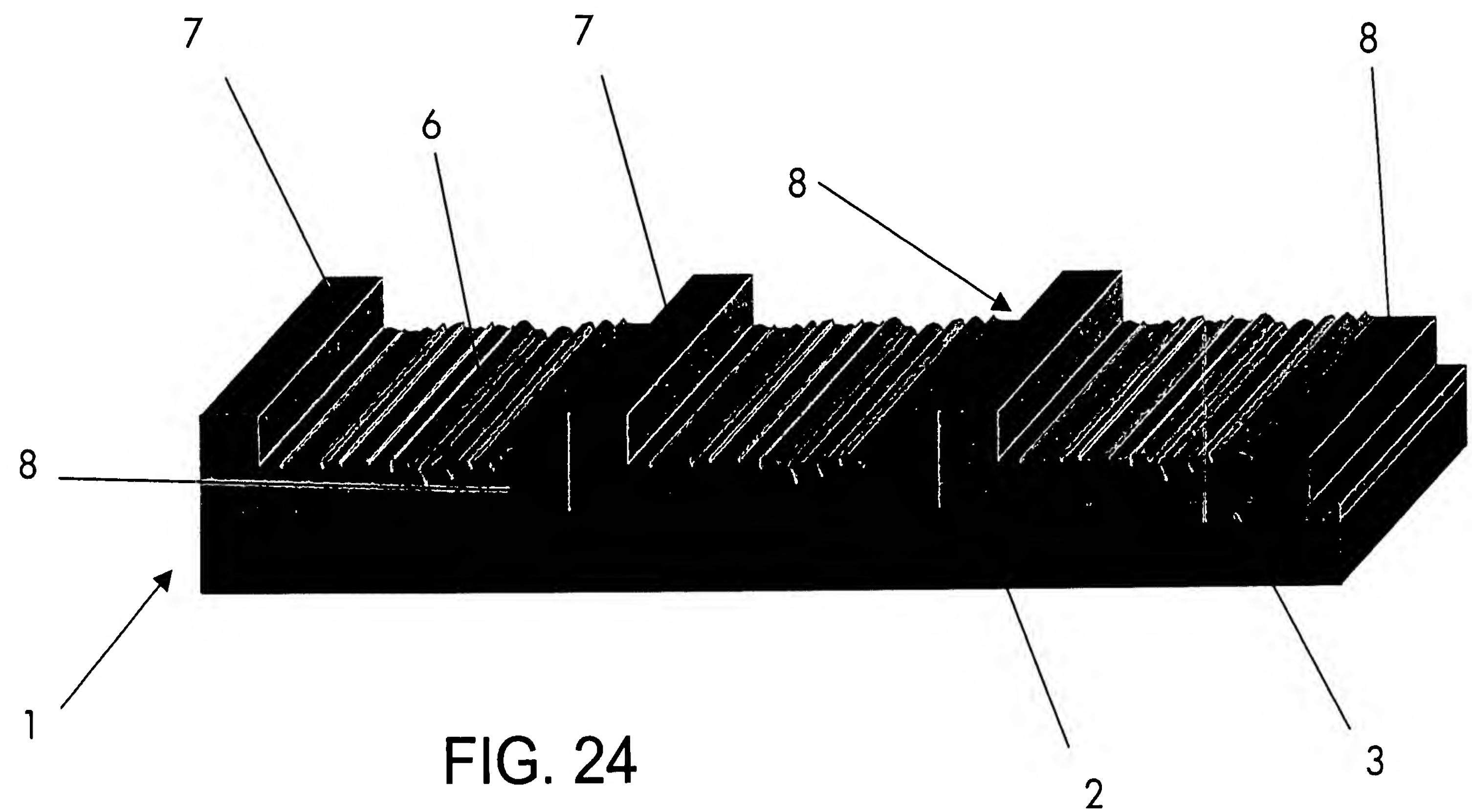

FIG. 24